HISTORICAL ASPECTS OF THE ANATOMY OF THE CARDIA WITH SPECIAL REFERENCE TO HIATUS HERNIA*

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INTEREST in the anatomy of the cardia as it relates to hiatus hernia was closely related in past centuries to human rumination. Human rumination or merycism seemed to captivate the imagination of physicians of previous times, and it was their desire to find an anatomic explanation for it, modeled on the four stomachs of the herbivorous split-hoofed animals. Figure 1 depicts the textbook description of the digestive apparatus of the cow with its four pouches: the rumen, the reticulum, the omasum, and the abomasum. This apparatus is by no means confined to cattle but is found also in camels, llamas, giraffes, deer, antelopes, sheep, and goats. Birds possess three stomachs: the crop, the prostomach, and the main stomach.

In 1838 Arnold described stomachs recovered from three ruminating individuals possessing a bulbar expansion at the top, separated from the stomach proper by a furrow or sulcus that later became known as Arnold's furrow and that we today apparently regard as the incisura cardiaca. He called the bulbar expansion above the stomach *Vormagen* (forestomach) and likened it to the rumen or paunch of the cow.

The incisura cardiaca, i.e., the angle formed by esophagus and stomach came soon under scrutiny because it was thought to hold the secret of gastroesophageal reflux, obviously a prime requisite for rumination. A. von Gubaroff, a Russian, investigated the animal kingdom, measuring the angle of the incisura in different species according to a formula developed by Smirnoff, and he concluded that the horse cannot vomit because it possesses the smallest angle, i.e., the deepest incisura.

In 1857 Luschka described the stomach of a 35-year-old ruminating

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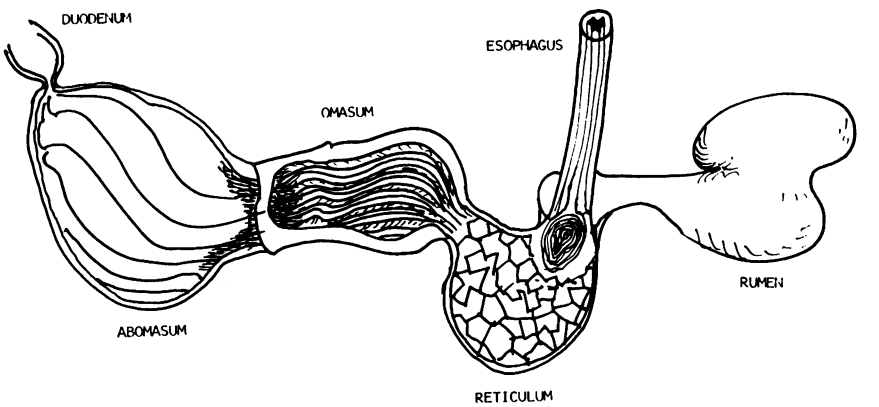

Fig. 1. Digestive apparatus of the cow.

woman with two expansions above the cardia, declaring he had found a true *Vormagen* in the upper of the two, whereas the lower one was merely an antrum cardiacum that had been mistaken by Arnold to be the former. Since then the term antrum cardiacum or cardiac antrum likewise has become an accepted term that has found its way into the official nomenclature of anatomy. Hyrtl in 1879 was the last one to list human rumination caused by a *Vormagen* as an entity, calling it a "*curiosum anatomicum rarissimum.*" The term itself fell into disrepute by the turn of the century, only to be resurrected in 1965 by J. D. Hollowell. However, the controversy lingered on, and the true anatomy of the cardia was yet to be explained.

P. Poirier and A. Charpy in successive editions of their textbook of anatomy described the lower esophagus as possessing a *fuseau broncho-diaphragmatique*, i.e., a spindle extending from the left main bronchus to the diaphragm and an *entonnoir infradiaphragmatique* or *terminal*, i.e., a terminal funnel, the latter of which seemed to coincide with Luschka's antrum cardiacum. In 1883 Laimer, a pathologist at the University of Graz, Austria, examined 60 cadavers and noted that the narrowest point of the esophagus lay invariably above the diaphragm. He published a table of the measurements on each case that permits the modern reader to construct his own distribution curve.

In 1898 Mehnert proposed the enteromere theory, according to which the esophagus was basically a string of pearls that developed from

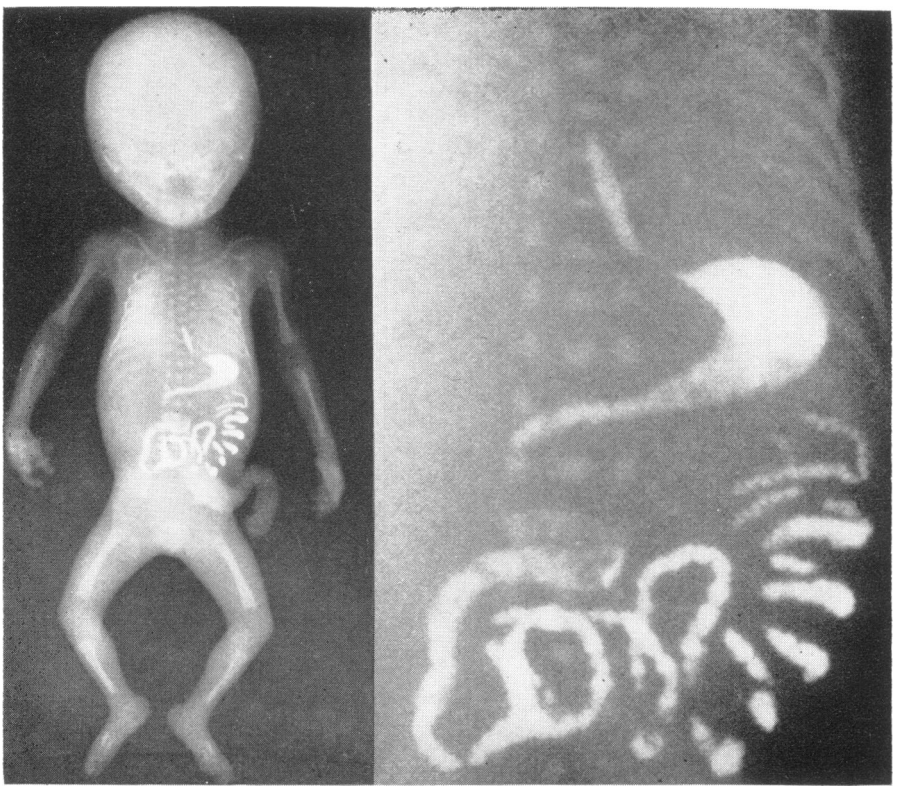

Fig. 2. Phrenic ampulla in a 3.5-month-old fetus; author's radiograph of a preparation by Dr. Edith Potter.

12 separate bubbles corresponding to the 12 thoracic segments. Enteromere No. 11 was equated by him to the *Vormagen*, enteromere No. 12 to the cardiac antrum. However, in the same year Otto Zusch countered this theory with the argument that there is no evidence of a segmental innervation of the esophagus, hence there could not be a segmental development of this organ. Finally, Hasse and Strecker in 1905, having been prompted by their late teacher, William His, Sr., used the term phrenic ampulla to describe a normal fusiform expansion of the lowermost thoracic esophagus, and this term has been accepted by anatomists. The authors state in their paper: "Although absent at birth, the phrenic ampulla forms in infancy." To dispute a minor point of their argument, I herewith submit the radiograph of a 4½-month-old fetus in which contrast material outlines a fusiform

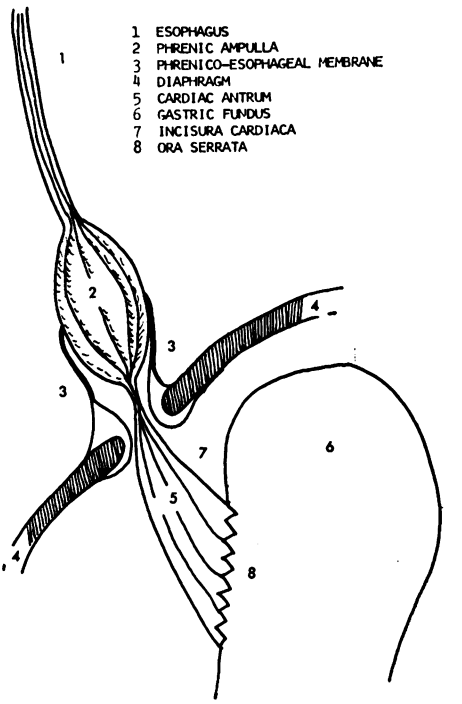

Fig. 3. Gastroesophageal junction in humans; majority view of anatomists.

expansion of the lower esophagus quite in keeping with the phrenic ampulla (Figure 2). Whatever the time of natural appearance of the phrenic ampulla is in a given individual, the year 1905 marks the official debut of the term phrenic ampulla in international anatomical circles. A majority viewpoint began to crystallize now among anatomists regarding the cardia, shown in Figure 3. A routine radiograph of the barium-filled cardia seems to support this diagram at least in part (Figure 4).

It took another 21 years, however, before radiologists began to take note of its existence, though successive editions of D. J. Cunningham Jr.'s *Anatomy* mentioned the existence of a phrenic ampulla as a normal anatomic structure, at least since 1912. Reich, in Vienna in 1926, was the first radiologist to demonstrate the phrenic ampulla radiographically and to correlate its contrast-filled image to a longitudinal section of a frozen cadaver. He and Hitzenberger also made paraffin casts of stomachs, demonstrating the cardiac antrum by this method as well as by radiography. They were inclined to consider the cardiac antrum to be

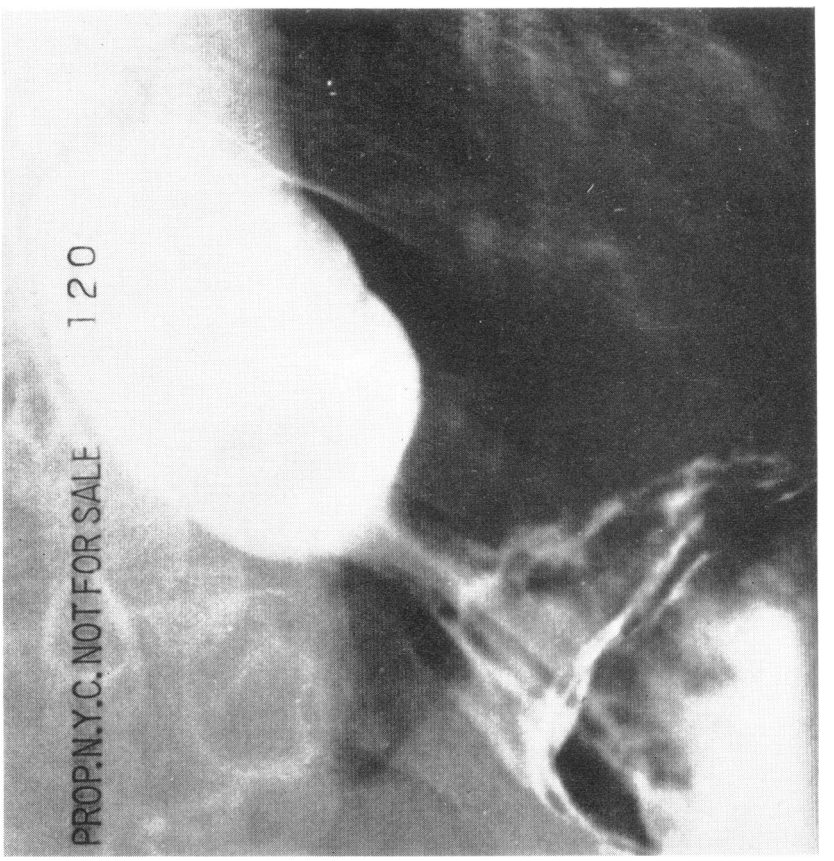

Fig. 4. Simultaneous demonstration of phrenic ampulla and cardiac antrum, the former filled with barium, the latter containing air. The barium-coated walls of the cardiac antrum suggest a border line between stomach and esophagus. This radiograph seems to refute the unitarian view held by a minority of anatomists and radiologists, according to which only a single "cardioesophageal vestibule" exists.

part of the stomach rather than the abdominal portion of the esophagus.

One might wonder what the radiologists had been doing between the turn of the century and 1926 when they first demonstrated the phrenic ampulla and the cardiac antrum. This in itself is fascinating history. W. B. Cannon and R. Moser in Boston were the first to study the anatomy and physiology of the cardia by means of contrast material. They made patients swallow capsules filled with bismuth. Bismuth was considered so poisonous at that time that they attached the capsules to strings that permitted them to pull the capsules out soon after they had passed the cardia. They noted that the capsules indeed were temporarily

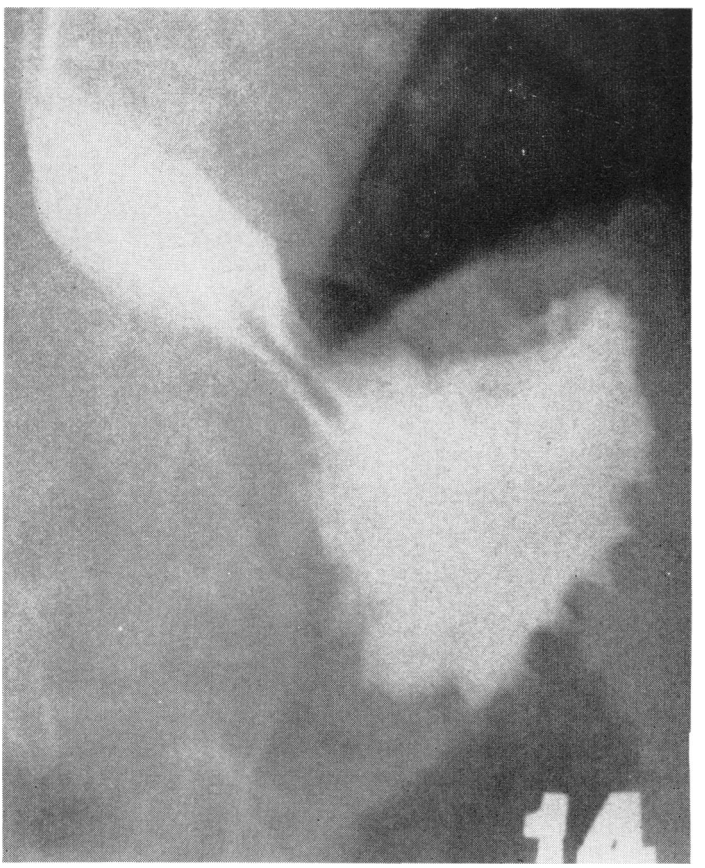

Fig. 5. Barium-filled funnel-shaped cardiac antrum, a zigzag border line is suggested here.

arrested immediately above the cardia. In 1899 Moriz Benedikt repeated the experiment with a mercury-filled bougie. In 1900 the United States radiologist Hirsch diagnosed the first hiatus hernia by means of x rays and a mercury-filled balloon. In 1904 Eppinger diagnosed the first hiatus hernia in a live patient, a diagnosis proved by autopsy, and it is interesting to note that he made his diagnosis first on the basis of auscultation and used x rays only to support his clinical judgment. In 1930, Markus Hajek, the otolaryngologist, described a special fluoroscope that permitted viewing the cardiac antrum to better advantage. With the ordinary fluoroscope or spotfilm device, the radiologist will miss the cardiac antrum because it is collapsed when the patient stands upright and is obscured by the gastric fundus when the patient lies

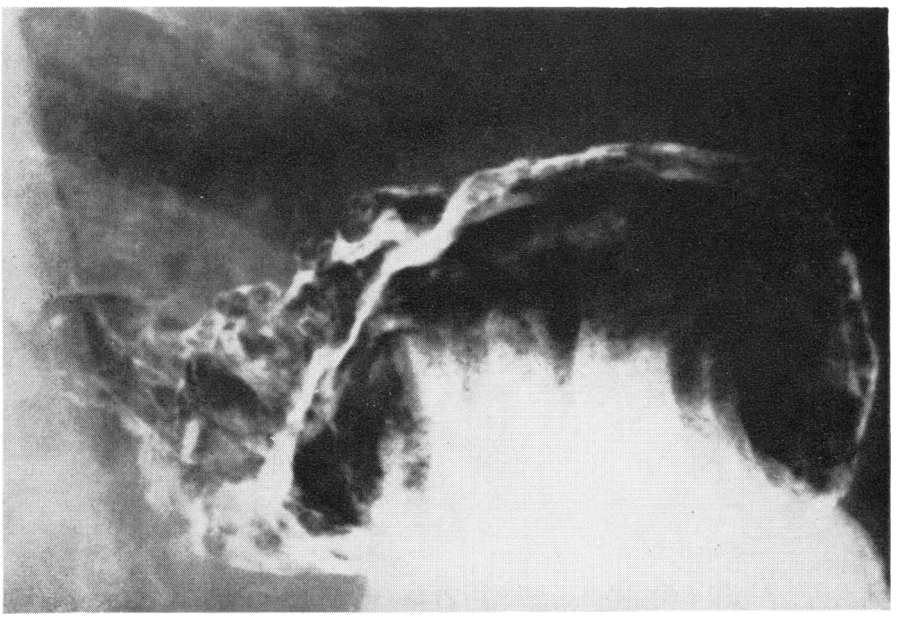

Fig. 6. Cardiac antrum, double contrast study, i.e., its wall coated with barium, its lumen filled with air.

supine. Hajek's machine permitted one to angle the x-ray tube toward the patient's head. In 1942 Dr. F. E. Templeton introduced me to the radiographic demonstration of the phrenic ampulla and showed me the existence of a ringlike indentation around its equator. Under his guidance, I exhibited such radiographs at the meeting of the American Roentgen Ray Society at Chicago, in 1942. Moreover, in his book *X-Ray Examination of the Stomach*, which appeared in 1944, he published two radiographs of a phrenic ampulla possessing an annular indentation. In 1953 Schatzki described a ring bisecting the phrenic ampulla that he thought to be pathological. It now bears his name and Schatzki ring is now considered a disease, while Templeton and I had heretofore considered it a normal anatomical structure frequently demonstrable in asyptomatic patients.

All these considerations did not seem to clarify the diagnosis of hiatus hernia since even a definition of this entity was lacking. At first it seemed simple to make the existence of a hiatus hernia dependent on the location of the border between esophagus and stomach. If it lay above the diaphragm the diagnosis of hernia appeared justified since

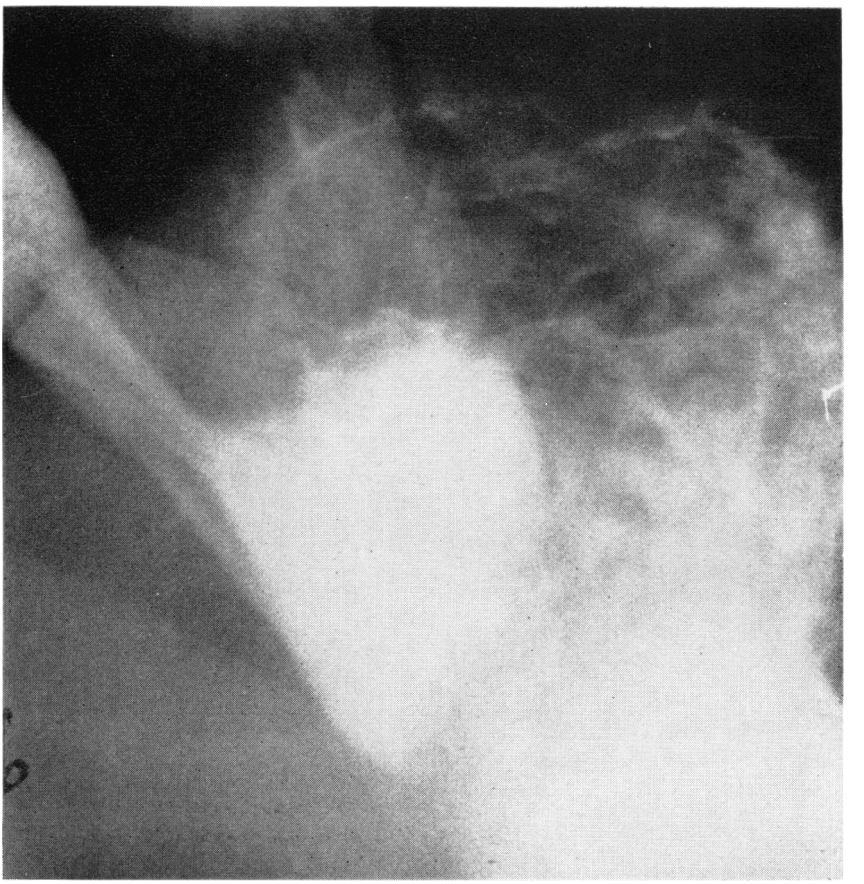

Fig. 7. Barium-filled funnel-shaped cardiac antrum without zigzag line. The gastric fundus is visible here through barium coating.

this would imply that indeed part of the stomach had been pulled into the thoracic cavity, unless—of course—this border line would *normally* reside in the chest. The question now crystallized into the need of first determining and locating the normal border line between esophagus and stomach. The older anatomists mentioned earlier, and also F. Magendie, described a distinct circular zigzag line marking the border between esophageal and gastric mucosa and named it ora serrata, nowadays frequently referred to as Z-line. They made it coincide with Arnold's furrow and the incisura cardiaca.

As early as 1841 Theile described a phrenicoesophageal membrane that arose from the diaphragm and inserted into the esophagus a few

Fig. 8. Cardiac antrum during the act of belching.

centimeters above the hiatus. Hyrtl elaborated on it in 1844 and called it phrenoesophageal ligament. The anatomist von Hayek stated in 1933 that this membrane inserts below the phrenic ampulla. In 1942 Templeton and I suspected that it may insert into the convexity of the phrenic ampulla and possibly coincide with the esophageal ring but we could not prove it. In 1956 Gary, as an associate of Schatzki, published in the *New England Journal of Medicine* a single case that came to autopsy; in it a Schatzki ring coincided with the mucosa border line. The photograph of the specimen is not convincing, however. In the early 1950's Sir Stanford Cade implanted silver clips into the esophagus through an

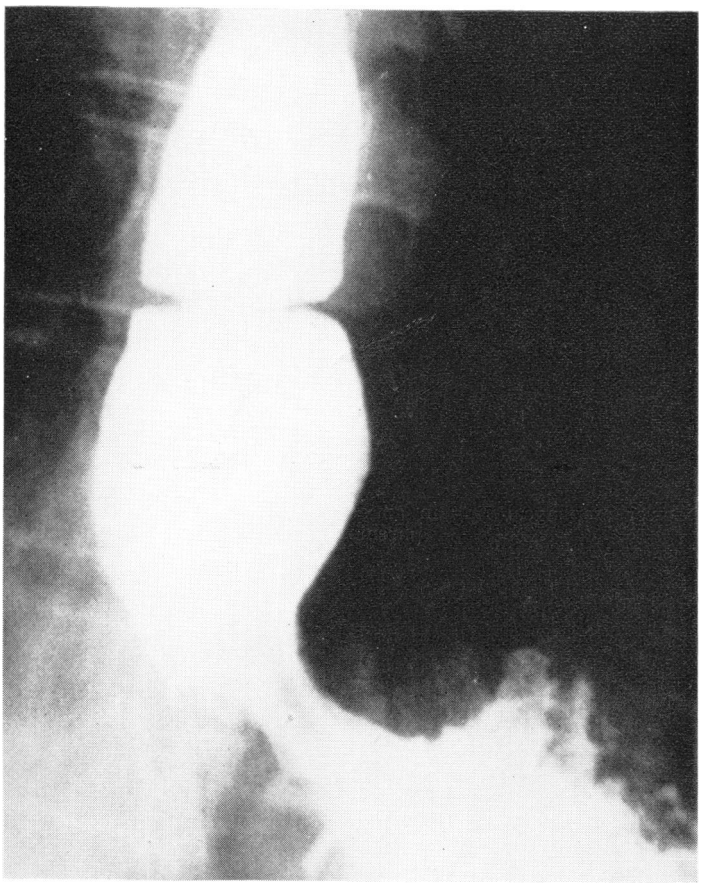

Fig. 9. Lower esophageal ring, transsecting the phrenic ampulla in an asymptomatic patient.

esophagoscope for the purpose of marking the mucosa border line. His radiologist reported then that these clips seemed to lie above the diaphragm. A similar approach is being taken currently by Dr. Charles Flood at the Columbia Presbyterian Medical Center, New York, N. Y., by introducing the endoscope down to the visible mucosa border line and then asking the radiologist to fluoroscope with the scope in place.

Obviously, if the mucosa border line indeed lies *normally* above the diaphragmatic hiatus, an additional element of confusion is introduced. Moreover, this difficulty is doubly compounded by a condition called "gastric-lined esophagus." It is being diagnosed with increasing frequency by some radiologists who consider it pathological. It is said

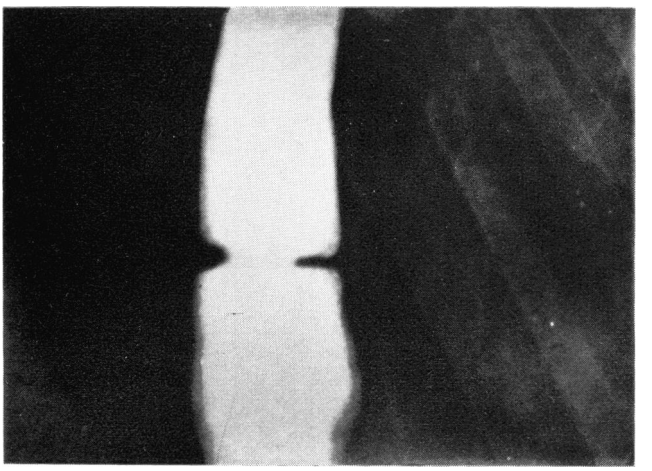

Fig. 10. Lower esophageal ring in an asymptomatic patient who did not exhibit a phrenic ampulla.

Fig. 11. Phrenic ampulla with two lower esophageal rings.

to be conducive to esophageal ulcers without gastroesophageal reflux as it occurs as an undesirable complication in some of the hiatus herniae. To moderate these opposing views, in regard to the location of the normal mucosa border line, one must quote Schaffer, who had been my teacher as chairman of the Department of Histology of the University of Vienna. In successive editions of his textbook of histology, he stated in the 1930's that there is an intermingling of gastric and esophageal epithelium near the gastroesophageal junction with the creation of gastric mucosa islands within the esophagus, so that one cannot truly speak of a distinct border between the two organs. Had the *Medical Tribune and Medical News* been aware of this, it could have saved itself considerable effort when on January 19, 1966, it printed a report headed: "Sharp Questions are Raised: Gastric Lining in Esophagus not Rare but 'Unrecognized.' "

It seems, then, that in the year of 1966 we have not come any closer to the solution. Radiographs of the cardiac antrum that I took suggest the existence of an ora serrata coincident with Arnold's furrow, in agreement with the older anatomists, but I cannot prove that the structure in question is indeed the mucosal border line (Figures 5 and 6). It is not always present (Figures 7 and 8).

An equal uncertainty exists at the present time about the significance of the lower esophageal ring. I for one believe that it is usually normal, for one can demonstrate its presence in about 80 per cent of asymptomatic patients by inducing the patient to swallow a very large bolus and to perform an extreme Valsalva test in Trendelenburg's position or by applying mild abdominal compression, or by having the patient cough vehemently (see Figures 9 and 10). In one instance, I have recently seen two esophageal rings, one on top of the other, separated by a distance of approximately 0.5 cm. (Figure 11). The frequency with which the lower esophageal ring can be observed in asymptomatic patients casts doubt also upon the theory that a visible ring constitutes a hiatus hernia, though some authors believe that indeed the presence of such a ring within the thoracic cavity is incontrovertible proof of diaphragmatic hernia. To illustrate the current disagreement, it is well to quote two papers, both of which appeared in December 1960 in two highly respected journals. In a paper entitled "The Lower Esophagus," published in the *American Journal of Roentgenology, Radium Therapy and Nuclear Medicine,* Walter S. Keyting *et al.*, under their subhead-

ing "Summary and Conclusions," state: "We unreservedly support the concept that the ring is the cardio-esophageal junction and that, therefore, when this ring is above the diaphragm, it indicates a hiatus hernia"; whereas Lauran D. Harris *et al.* in a paper entitled "Relation of the Lower Esophageal Ring to the Esophagogastric Junction," published in the *New England Journal of Medicine*, state under an identical subheading "The lower esophageal ring cannot be relied upon to mark the esophagogastric junction."

CHRONOLOGICAL TABLE

Arnold, F.	1838	*Eppinger, H.	1904
Theile, F. W.	1841	Hasse, C. and Strecker, F.	1905
*Hyrtl, J.	1844	*Reich, L.	1926
Luschka, H.	1857	*Hajek, M.	1930
*Hyrtl, J.	1879	*Schaffer, J.	1930
*Laimer, E.	1883	*Hayek, H. von	1933
Gubaroff, A. von	1886	Templeton, F. E.	1942
Smirnoff, P.	1886	Cade, S.	ca. 1950
Mehnert, E.	1898	Schatzki, R.	1953
Zusch, O.	1898	Gary, J. E.	1956
Cannon, W. B. and Moser, A.	1898	Keyting, W. S. *et al.*	1960
*Benedikt, M.	1899	Harris, L. D. *et al.*	1960
Hirsch, I. Seth	1900		

To summarize the historical events that contribute to our present knowledge or ignorance of the roentgen anatomy of the cardia, one might refer to the Table in which most of the authors quoted in this paper are listed in chronological sequence. Those preceded by an asterisk belong to the Graz–Vienna–Prague orbit, as is proper to point out to members of this society. Dr. Leo Reich is not only alive and well as a practicing radiologist in Arizona, but is also an active member of this society.

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